Prevent 2,4-D INJURY
To Crops and Ornamental Plants

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Circular 808

Operating a 2,4-D sprayer this way causes extreme misting and endangers nearby susceptible crops.

THE WIDELY USED HERBICIDE 2,4-D[1] when carelessly applied may severely injure or kill a wide variety of broadleaf crop and ornamental plants.[2] They include among others such plants as tomatoes, snap beans, soybeans, melons, grapes, cotton, roses, chrysanthemums, redbud trees, and birch trees. Some of these plants are more susceptible to injury from 2,4-D than the common broadleaf weeds.

Using 2,4-D on lawns and other grassy areas, in corn and grain fields, along fence rows, highways, drainage ditches, railroads, and under power lines has caused widespread damage to fields and gardens. Mist or vapor from 2,4-D has damaged susceptible plants growing a half mile or more from the area actually sprayed. Much of the damage from this valuable agricultural chemical can be avoided if users are aware of the dangers in its application.

The purpose of this circular is: (1) to describe and illustrate the symptoms of 2,4-D injury on some of the more common susceptible crops and ornamental plants; (2) to characterize the commercially available forms of 2,4-D; (3) to discuss kinds of exposure of crops to 2,4-D; (4) to give information concerning the factors that influence the drift of mist; and (5) to suggest ways in which 2,4-D can be used to control weeds with the least chance of injury to crops and ornamental plants in the neighborhood. Injury resulting from the application of 2,4-D by airplane or as a dust is not discussed, since it is unlikely that anyone in Illinois would apply this chemical by these extremely hazardous methods.

Symptoms of 2,4-D Injury

General. All broadleaf weeds or crop plants susceptible to 2,4-D injury respond in about the same way. As a general rule, the higher the concentration of 2,4-D to which the plant is exposed, the more severe the degree of distortion or other damage to the various parts of the plant and the greater the chance the plant will be killed. The development of symptoms and death of the plant generally occur most rapidly during warm, sunny weather in the early part of the season when the plant is growing the fastest. Plants are least likely to be

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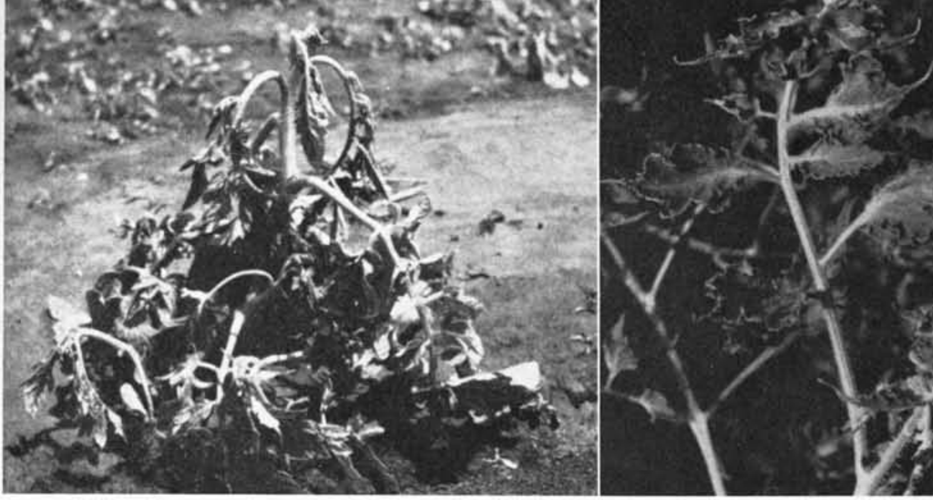
[1] The herbicide commonly known as 2,4-D is 2,4-dichlorophenoxyacetic acid.

[2] **The herbicides 2,4,5-T and MCPA may severely injure crop plants and cause symptoms similar or identical to those of 2,4-D injury.** The herbicide commonly known as 2,4,5-T is 2,4,5-trichlorophenoxyacetic acid and that known as MCPA is 2-methyl-4-chlorophenoxyacetic acid.



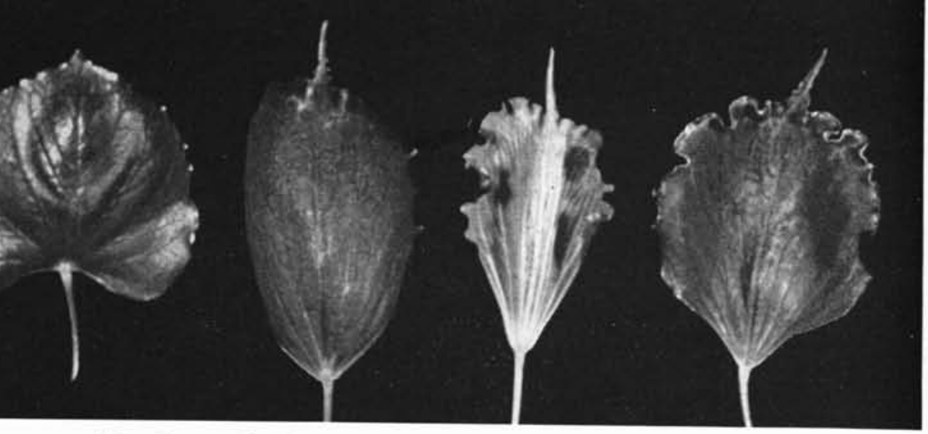
(*Left*) tomato plant sprayed directly with 2,4-D at a concentration used for weed control. The plant shows the beginning symptoms of injury as they appeared 24 hours after it was sprayed. (*Right*) upper part of a tomato plant as it looked several days after it was exposed to 2,4-D mist. The wavy margins and drawn out tips of the leaflets are typical symptoms of 2,4-D injury. (Fig. 1)

susceptible to injury when growing in soil that is relatively dry or low in fertility.

If 2,4-D is sprayed directly on a susceptible plant at a concentration used for weed control, the first symptoms may appear within 3 to 4 hours. Drooping (epinasty) and wilting of the uppermost leaves is one of the first symptoms in most herbaceous plants (Fig. 1). The upper part of the stem in herbaceous plants (Fig. 8, page 9) and the tip growth in woody plants gradually become twisted and curled. All shoot and root growth stops. The stem and tap root may split open near the soil line. The plant usually dies within 2 or 3 weeks.

If 2,4-D contacts the plant only in the form of an air-diluted, fine mist, or as a vapor, symptoms develop less rapidly and the initial effect on the plant may be less severe. Beginning symptoms may not be noticeable until they appear on new, expanding leaves a week or more after exposure. Leaves or leaflets have wavy or frilled margins and begin to look like folding fans; the tips become drawn out to a fine point (Fig. 1). Inward cupping or curling of the leaves is a common symptom in plants such as grapes and redbud trees. The veins become more prominent than usual and often appear to be almost parallel to each other (Fig. 2). Dropping of the flowers after exposure is common in some plants. New shoots that develop after exposure are likely to be spindly with the parts of the stems between leaves longer than normal (Fig. 3).

Symptoms of 2,4-D injury may continue to appear in the leaves and shoots for a period of several weeks following first exposure. After



The three redbud leaves on the right have been injured in varying degrees by 2,4-D mist. Note the frilled margins, cupping, nearly parallel veins, and elongated tips of the leaves. The leaf on the left is normal. (Fig. 2)

this period, normal leaves and shoots will develop (Fig. 4) unless the plant has been exposed again later. Thus, new and nonaffected growth of the top of plants such as tomatoes will often cover up symptoms of previous injury on the older, lower leaves.

A delay of several weeks or even months in the appearance of symptoms of injury is not uncommon in woody plants if exposure occurs at or near the end of the growing season. At the New York (Cornell) Agricultural Experiment Station it was found that if certain woody plants such as Tartarian honeysuckle and lilac were sprayed with 2,4-D in the fall, symptoms of injury did not appear until the following spring. The outstanding symptoms were delayed bud break, prominent leaf veins, distortion and thickening of the leaf blades, and a tendency toward bunching of the terminal growth.

If 2,4-D is sprayed on the soil near plants, it may be absorbed

The two grape branches at the left and the center leaf have been injured by 2,4-D mist. The branch at the right is healthy. (Fig. 3)

This redbud branch shows the effects of 2,4-D injury. Beginning with the bottom leaf at right and continuing upward and across through the 10th leaf, all leaves show injury, the first 6 showing increasingly severe injury. From the 7th through the 10th leaf, leaves have begun to recover. The 10th leaf shows only slight injury. The remaining leaves are normal. (Fig. 4)

through the roots, transported to the top of the plant and cause severe injury to the foliage. Symptoms may not appear until several weeks after application.

Tomatoes. If a plant has been exposed to relatively low concentrations of 2,4-D, the flowers may drop off so that fruit set is poor. The fruit may become heart-shaped and tend to ripen when small, or if the plant is sprayed directly with 2,4-D, the fruit may crack open or become severely deformed (Fig. 5). Clumps of thick, aerial roots may develop on the underside of stems or branches near the ground.

Symptoms similar to those brought about by 2,4-D may be caused by environmental factors, infectious diseases, and chemicals other than herbicides. When fruit-setting compounds[1] are sprayed on the foliage,

[1] Chemicals such as para-chlorophenoxyacetic acid and beta-naphthoxyacetic acid are sometimes sprayed on individual flower clusters to induce fruit set under unfavorable environmental conditions or to produce so-called "seedless" fruit.

The cracks in these tomatoes are the result of injury by direct spraying with 2,4-D. The three heart-shaped fruit at the top developed on plants injured by 2,4-D mist. *Courtesy of N. F. Oebker.* (Fig. 5)

they may produce symptoms of injury that are indistinguishable from those caused by 2,4-D. Too little or too much nitrogen in the soil, average night temperatures below 55° F. or above 70°, or average day temperatures above 90° may cause tomato flowers to drop. Diseases such as early blight, Septoria leaf spot and bacterial leaf spot that cause lesions on the flower stalks may bring about flower drop and poor fruit set.

Symptoms of 2,4-D injury may be confused with those of cucumber mosaic alone or in combination with common tobacco mosaic. These virus diseases may result in severe leaf distortion in tomatoes with the leaflets consisting of little more than the midrib so that they have a "shoestring" effect. Some vein-clearing in the leaflets may also occur. In combined virus infections, the fruit may be deeply ridged with a protuberance (knot or bump) at the blossom end. In the beginning stages of infection, however, the leaflets generally show a light and dark green mottling (or mosaic) and the plants are dwarfed and yellow with shortened stalks between leaves. The leaflets are not fan-shaped and there is no tendency for the veins to be parallel to each other as in 2,4-D injury. Usually less than 5 percent of the plants in an outdoor planting exhibit symptoms of cucumber mosaic, while practically all the plants in an area affected by 2,4-D will show some degree of leaf distortion.

Grapes. These plants, both cultivated and wild, are perhaps the most sensitive of all plants to 2,4-D. For this reason, grapevines are often useful as an indicator of whether 2,4-D has contaminated a farm or garden. Common symptoms include leaf dwarfing and curling, development of fan-shaped leaves, and a tendency toward the development of small finger-like projections from the leaf margin (Fig. 3). Older leaves may become limp, crinkled, and twisted with wider, yellower, and more prominent veins than usual. The texture of the tissue between the veins may be somewhat rough and pebbly. Exposure to 2,4-D during the closed bud and flower stages causes severe injury by preventing fruit set and development. Since grapes are perennials, the effect of severe 2,4-D injury may be carried over from one year to the next.

Fan leaf,[1] a soil-borne virus disease of grapes transmitted by at least one species of nematode, has leaf symptoms with some resemblance to those induced by 2,4-D. The fan-leaf symptoms, however, appear only in leaves at the base of the canes or in those formed in the early season growth, while the symptoms of 2,4-D injury may affect young leaves at any position on the cane depending on the time of exposure. Young leaves on plants infected by the fan-leaf virus may have light and dark green mottling or mosaic. Internodes are usually shorter than normal and the entire vine is dwarfed. In the beginning stages of infection, the distribution of fan leaf in a vineyard is likely to be irregular, but the pattern of 2,4-D injury will be more or less uniform.

Snap beans and soybeans. Symptoms of 2,4-D injury on beans include wilting and distortion of the leaves (Figs. 6 and 7), curvature of the stem, flower drop, and the development of side branches at the junction of stem and leaves. A puckering of the young leaflets sometimes occurs. In soybeans, curvature of the stem and failure to set pods as a result of exposure in midseason are most apparent after the plants have matured and lost their leaves. Poor pod set, however, may be brought about by unfavorable weather and curvature of the stem may result from lodging following wind and rainstorms.

Injury to beans from 2,4-D may be confused with symptoms of one or more of the common virus diseases. Soybean mosaic may cause leaf distortion and a puckering of the tissues over the entire leaflet, or in some varieties, only along the midrib. Mosaic-affected leaves

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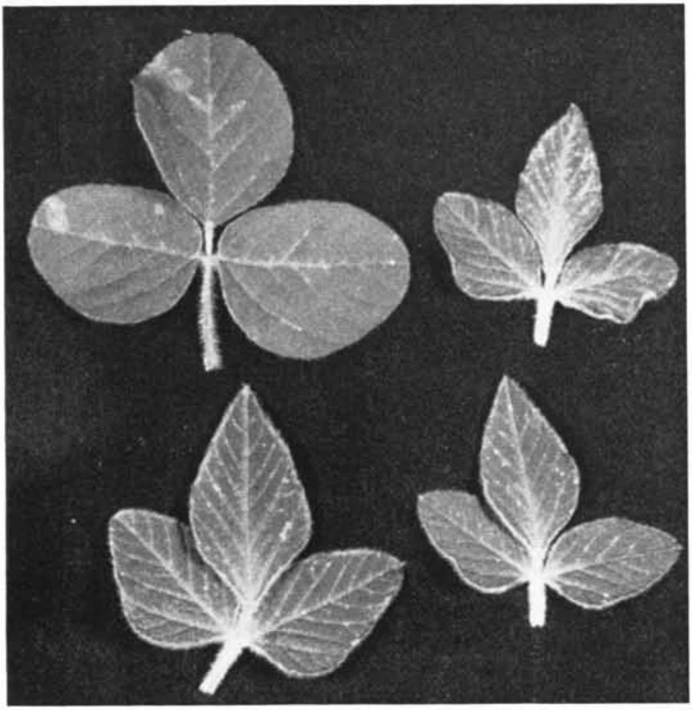
[1] Fan leaf has not been reported from Illinois although it is a destructive disease in California vineyards.

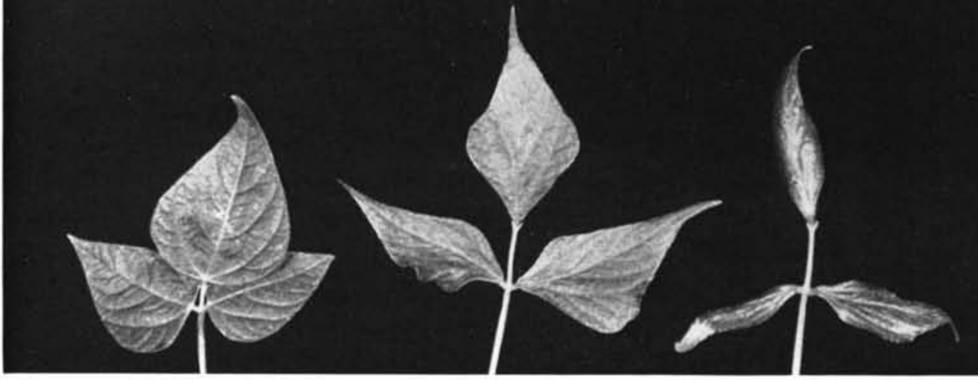


(*Top left*) healthy Harosoy soybean leaf. Remaining leaves show varying degrees of distortion as a result of injury by 2,4-D mist. (Fig. 6)

generally show a light and dark green mottling. In varieties of soybeans grown for oil, leaf distortion from mosiac tends to disappear in midsummer, but persists in the vegetable varieties. Other symptoms of mosaic diseases are yellowing and downward curling of the leaf margins and stunting of the entire plant. Pods may be smaller and flatter than usual and yields reduced.

In snap beans, mosaic diseases cause distortion and downward cupping of the leaves, as well as light and dark green mottling. The leaflets may be longer and narrower than usual. The top of the plant may curve downward. Plants are often dwarfed, yellow, and fail to set pods. In plants affected by the mosaic diseases, the tendency of the leaflets to be fan-shaped and the veins to be parallel as in 2,4-D injury is less pronounced or entirely lacking.

In soybeans the pattern of 2,4-D injury will be more or less uniform in the border of the field or throughout any contaminated area. But the pattern of mosaic disease will be irregular since it is uncom-



(*Left*) healthy snap bean leaf. Center leaf shows moderate injury by 2,4-D mist and leaf at right severe injury. (Fig. 7)

mon for more than 1 percent of the plants to show symptoms. In snap beans where a high percentage of the plants may be affected with common mosaic, any dependence on the pattern of distribution of the disease is likely to be misleading. Under these circumstances, finding fan-shaped leaves with veins tending to be parallel to each other and the absence of green or yellow mottling suggests 2,4-D injury.

Peony stem and leaves severely distorted as a result of exposure to 2,4-D mist. *Courtesy Illinois State Natural History Survey.* (Fig. 8)

Types of 2,4-D in Common Use

The types of 2,4-D commonly used can be classified as esters and salts. The most widely used salts are the amines. The 2,4-D esters are of two kinds — high-volatile or low-volatile.

High-volatile esters when sprayed on vegetation may give off plant-toxic vapors for as long as 3 days after they are applied. These esters include the methyl, ethyl, propyl, butyl, amyl, and pentyl series. One of these might be identified on the container label under "active ingredients" as "Butyl ester of 2,4-dichlorophenoxyacetic acid."

Low-volatile esters are less likely to give off plant-toxic vapors than the high-volatile esters. Certain of these forms, however, may volatilize and produce vapors at temperatures above 90° F. The low-volatile esters include butoxyethyl, polypropylene glycol, tetrahydrofurfuryl, ethylene glycol butyl, propylene glycol butyl, polyethylene glycol, butoxy polypropylene glycol, butoxy ethoxy propyl, polypropylene glycol butyl, and iso-octyl series. A listing of one of these on the container label under "active ingredients" might be "2,4-dichlorophenoxyacetic acid, propylene glycol butyl ester." The label also generally specifies "low volatile," "low volatility," or "LV."

Amines of 2,4-D are theoretically not volatile and should not give off plant-toxic vapors. The amines include the dimethyl, ethanol, diethanol, triethanol, isopropanol, and dimethyl diethyl series. A listing of one or more of these on the container label under "active ingredients" might be "Alkanolamine salts of the ethanol and isopropanol series of 2,4-dichlorophenoxyacetic acid."

The actual concentration of active ingredients in both esters and amines is expressed in terms of percentage of 2,4-D acid or in pounds of 2,4-D acid per gallon.

Kinds of Exposure

Plants may be injured or killed if they are sprayed directly with 2,4-D or if exposed to its mist or vapor. Injury may also be caused by the percolation of 2,4-D through the soil to the roots of the plants.

Exposure of plants to direct spraying results when the operator of the sprayer, in spraying roadside or fence rows, overshoots the weeds with a spray boom or hand gun and hits adjacent crops. The spray of any form of 2,4-D is almost sure to kill most broadleaf crop plants.

Exposure of plants to mist may result from practically all kinds of spraying with 2,4-D, but particularly where the sprayer is not correctly operated. Injury from mist has been widespread in Illinois. Much of this damage has originated from cornfield spraying. Severe injury or death may be caused by only a few, tiny droplets falling on each plant.

Exposure of plants to vapor may occur in the vicinity of lawns, parks, cemeteries, and other grass areas sprayed with high-volatile esters. Trees, shrubs, flowers, and garden vegetables may be injured in this fashion. The distance that vapor will travel and be injurious is not known with certainty since it is impossible to distinguish mist injury from vapor injury. It is presumed that under near-calm conditions the distance may be several hundred feet.

Exposure through the soil and subsequent absorption of 2,4-D through the roots may follow if excessive amounts of the chemical are sprayed on the soil close to trees and shrubs. Damage may also be caused by spraying the weed killer on slopes that permit it to be carried to the base of the plants by surface water.

What Affects Injury From Mist

The extent and severity of injury to susceptible plants from drifting 2,4-D mist[1] is influenced for the most part by: (1) the way the sprayer is adjusted and operated; (2) the concentration of the chemical in the air; and (3) the length of exposure.

The way the sprayer is adjusted and operated will determine the degree to which the spray will be broken up into fine droplets or mist. All spray equipment now employed for applying 2,4-D in water discharge a spray pattern containing both large and small droplets. The smaller the droplets, the longer they will be suspended in the air and the greater the chance of their drifting away from the sprayed area onto susceptible crops. It has been calculated that spray droplets 1/1000 inch in diameter if released from a height of only 10 feet above ground in a 3 mile per hour wind may be carried as far as 1 mile before settling to the ground.

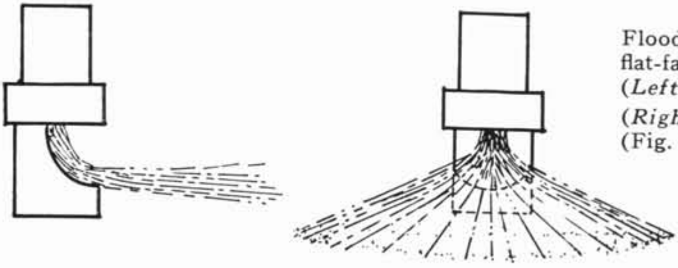
Even a relatively small difference in the size of the droplets has a great effect on the distance of drift. At a typical application rate of 10 gallons of liquid per acre, a spray made up entirely of droplets 1/1000 inch in diameter would deposit 700,000 drops per square inch. If all droplets were 4 times larger or 4/1000 inch in diameter, the deposit would be 11,500 drops per square inch. This is still far more than would be needed for good weed control. These droplets 4/1000 inch in diameter, however, would drift only 50 feet under the same conditions in which the 1/1000-inch droplets could drift up to 1 mile.

[1] The same factors that influence the horizontal and vertical movement of mist also affect the drift of vapor.

Spraying pressure and nozzle type and size will all directly affect the proportion of fine droplets or the amount of mist in the spray cloud or pattern. The lower the pressure, the larger the average size of the droplet. With a typical flat-fan nozzle, a decrease in pressure from 60 to 20 pounds per square inch can double the size of the average droplet. It can also decrease by 4 or 5 times the number of fine droplets capable of drifting great distances.

Nozzle design influences the degree of misting. The flooding types (Fig. 9) of flat-fan nozzles emit a spray made up of droplets about 50 percent larger in average diameter than the conventional, flat-fan types. The conventional flat-fan nozzles (Fig. 10) in turn produce a spray pattern composed of larger droplets than that produced by the hollow-cone (Fig. 10) or full-cone nozzles. All flat-fan types give satisfactory coverage of broadleaf weeds.

Nozzle-orifice size also affects the size of the droplets. The smaller the nozzle orifice of the same design, the finer the droplets. Larger nozzle orifices can be used for any method of application by: (1) wid-



Flooding type flat-fan nozzle. (*Left*) side view. (*Right*) front view. (Fig. 9)

(*Left*) Hollow cone nozzle. (*Right*) Regular flat-fan nozzle. (Fig. 10) ening the nozzle spacing on the boom; (2) increasing the amount of liquid applied per acre; (3) increasing the ground speed; and (4) decreasing the pressure.

Concentration of the chemical in the air will be governed by the amount of actual 2,4-D applied per acre, the degree to which the spray is broken up into fine droplets, and the movement of air. For example, ½ pound of 2,4-D acid applied in 10 gallons of water to the acre will produce a mist twice as concentrated as ¼ pound applied in 10 gallons of water per acre.

Length of exposure is regulated to a great extent by the size of the area sprayed, wind direction and velocity, and air temperature. For instance, spraying a 50-acre cornfield with ½ pound of 2,4-D acid to the acre will potentially expose a neighboring tomato field to the mist for a longer time than spraying a 25-acre field at the same dosage. The effect the direction of ground wind has in carrying mist toward or away from susceptible crops in the vicinity is obvious. If the velocity is high enough to carry the mist away from these crops, the chance of damage will be decreased.

Temperature is known to influence the vertical movement and diffusion of mist just as it does smoke. In this connection, however, the rate of temperature increase or decrease from ground level to a height of 50 feet or more may be of greater importance than temperature at ground level alone. Actually, there is no way to predict the effect of air temperature on the movement of mist. In California, the smoke from smoke bombs or burning rubber tires has been used to determine the vertical and horizontal movement of air currents before spraying with 2,4-D by airplane. In this way the danger of mist drifting to susceptible crops has been lessened.

How to Prevent Injury

Do not use the high-volatile esters of 2,4-D and 2,4,5-T unless you thoroughly understand the dangers of using them and are willing to take the necessary precautions. Do not use any form of these herbicides, including the high-volatile and low-volatile esters, the amines, and other salts within ½ mile of sensitive crops such as tomatoes and grapes. Do not be lulled into a feeling of complacency just because you have heard that the low-volatile esters and salt formulations are safe. These forms do not vaporize as readily as the high-volatile esters, but the droplets of spray can be carried just as far by the wind.

Read the directions on the container label carefully. Pay special attention to the precautions necessary to avoid damage to susceptible crops.

Use a reasonably high gallonage of water per acre and as low a pressure as possible. The amount of liquid spray applied in the neighborhood of susceptible crops should never be less than 10 gallons per acre and preferably more. Twenty pounds of pressure per square inch with conventional flat-fan nozzles produces larger droplets than 40 pounds per square inch and yet gives adequate coverage of broadleaf weeds.

Use wide nozzle spacings and keep the nozzles as close to the ground as possible. You can get wider nozzle spacings by using wide-fan-angle types of nozzles and rotating the boom on its axis so the nozzles spray back and down onto the foliage rather than straight down. The nozzles can be placed nearer to the ground if they are the wide-fan-angle type. Use only enough overlapping of spray patterns to get adequate coverage. Avoid double overlapping because by so doing you must increase the height of the boom.

Use as high a ground speed as is reasonable and safe. Using a higher ground speed, a higher gallonage, lower pressure, and wider nozzle spacings will let you use nozzles with larger orifices. The result will be a much coarser droplet of spray and less drift.

Use the flooding type of flat-fan spray nozzles if you are spraying weeds in the vicinity of susceptible crops. They give adequate coverage of broadleaf weeds at pressures as low as 10 pounds per square inch. The flooding type of nozzle employs a circular orifice spraying onto a sloping flat surface to spread the spray (Fig. 9). Such a nozzle produces a wider angle of spray made up of droplets the average diameter of which is about 50 percent larger than that produced by the flat-fan types normally used. The fan angles and output of Spraying Systems nozzle tips ⅛ K 1, ⅛ K 1.5, ⅛ K 2, and ⅛ K 3 (or their equivalents) are satisfactory for applying 2,4-D. They can very easily be used at spacings of 40 inches, but regular flat-fan nozzles usually work best at spacings of about 20 inches.

Never try to increase the output of the sprayer by raising the pressure. While raising the pressure will increase the output slightly, it will increase the number of fine droplets much more rapidly than it does the output so the tendency of the spray to drift is much greater. You can get a higher output and produce larger droplets by changing the orifice of the nozzle to a larger size. In this way, you reduce the danger of drift.

Keep one sprayer solely for using 2,4-D and 2,4,5-T. Removing all traces of these chemicals from the tank, pump, supply lines, and nozzles by washing and rinsing is extremely difficult.

If you are spraying 2,4-D on roadside, ditch banks, and under power lines, survey the route carefully beforehand and locate susceptible crops. Use smoke trails to determine wind direction and plan your operations so that wind and air currents will not carry the mist in the general direction of these crops. Make sure your employees know they are using 2,4-D and that they know about its hazards.

When you are using knapsack or power sprayers with a hand-held gun or boom on lawns or other grassy areas, use low pressure and direct the spray downward to make sure that a minimum of mist is discharged into the air. When you spray grass areas near or around trees and shrubs, use only enough 2,4-D to wet the leaves of the weeds lightly. Do not use 2,4-D on slopes immediately above valuable plants.

When you buy insecticides and fungicides, insist that they be in factory-sealed containers. Do not accept them in used containers that may be contaminated with 2,4-D or 2,4,5-T.

Granular formulations of 2,4-D are safer to use on lawns and other grass areas in the neighborhood of susceptible vegetable and ornamental plants than liquid sprays. The granules are less likely to volatilize than liquid forms. Granules are widely available either alone or mixed with fertilizer.

The new, inverted-emulsion forms of 2,4-D and 2,4,5-T are available for weed and brush control. When they are properly mixed, the invert forms are much thicker than the conventional liquid sprays. Their consistency approaches that of mayonnaise. These materials do not break up into small particles while they are being applied but remain as large drops. Preliminary tests indicate that the invert emulsions are not likely to be wind-borne.

Ammate and Dybar are two chemicals that can be used for brush control. Both compounds will give adequate brush control and both are much safer to use in areas where sensitive plants are growing than 2,4-D or 2,4,5-T. Dybar is a pelleted herbicide and can be applied by hand to the surface of the soil near the brush.

Several new, pre-emergence herbicides for use in cornfields have been developed and tested. Although they are slightly more expensive than post-emergence sprays of 2,4-D, their use should eliminate any hazard from drifting vapor or mist. If possible, substitute one of these newer herbicides for 2,4-D if you want to spray weeds in cornfields adjoining sensitive crops. For information concerning these chemicals, write to the Department of Agronomy, University of Illinois, and ask for mimeographed leaflet AG 1816.

How to Recognize 2,4-D Injury

If you find the following symptoms or conditions, you can suspect that your plants have been injured by 2,4-D.

1. Fan-shaped leaves with wavy or curled margins and prominent veins tending to be parallel to one another. Look for these symptoms in all plants in the area you suspect has been contaminated with 2,4-D and look for them especially in wild and cultivated grapes because these plants are very sensitive to 2,4-D.

2. Drooping leaves in the tip growth of tomato plants. In young trees and shrubs such as box elder, birch, redbud, and grapes, look at the tips of the branches. If 2,4-D has injured them, they will appear to be stretching out to an abnormally long length.

3. Look at all the susceptible plants in the affected area. Practically all of them should show symptoms 1 and 2.

Some of the symptoms of 2,4-D injury can be confused with those of important infectious diseases of the crop. There are times, therefore, when to get a positive diagnosis of 2,4-D injury, you may need the help of some one who is familiar with both symptoms of disease and of 2,4-D injury.

This circular was prepared by M. B. LINN, Professor of Plant Pathology, F. W. SLIFE, Associate Professor of Crop Production, and B. J. BUTLER, Assistant Professor of Agricultural Engineering.

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